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TECHNICAL REPORT
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Feasibility of Applying Ohmic Heating and Split-Phase Aseptic Processing for Ration Entree Preservation

by

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Two methods of food sterilization were studied with a variety of foods. The methods were ohmic heating and split-phase aseptic processing. The method of operation of these systems is discussed in depth. The final products were tested by a sensory panel. Products from both systems compared favorably to thermally processed tray pack items. The recipes used for these products were identical to the tray packs. Although the products received satisfactory ratings, they could be improved by using formulations specifically developed for the systems. The study demonstrated that either of these reduced-temperature sterilization processes will produce an acceptable product that is an alternative to thermal sterilization.

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CONTENTS

	Page
1. INTRODUCTION	
Ohmic Heating (OH)	1
Split-Phase Aseptic Processing (SP)	2
2. EXPERIMENTAL RESULTS	
Ohmic Heating	2
Phase 1: Processing	3
Phase 1: Sensory Testing	3
Conclusions	6
Phase 2: Processing	6
Split-Phase Aseptic Processing	6
Phase 1: Processing	7
Phase 2: Processing	8
Phase 2: Sensory Testing	9
3. DISCUSSION OF RESULTS	11
4. REFERENCES	13
APPENDICES	
A. Description of Ohmic Heating	14
B. Commericial Sterility Testing Procedure	16
C. Products and Ingredients	18
D. Description of Split-Phase Aseptic Processing	26

LIST OF ILLUSTRATIONS

Figure		Page
1	Schematic Diagram of Ohmic Heating	15
2	Schematic Diagram of Aseptic Processing	27

Table		Page
1.	Processing Conditions for OH Products (Phase 1)	3
2.	Sensory Results of OH Products (Phase 1)	5
3.	Processing Conditions for OH Products (Phase 2)	7
4.	Processing Conditions for SP Products (Phase 1)	7
5.	Processing Conditions for SP Products (Phase 2)	9
6.	Sensory Results for OH, SP and TP Products (Phase 2)	10

Preface

The information in this report is based on a series of research contracts that were conducted to determine the feasibility of using two novel methods of food preservation: Ohmic Heating and Split-Phase Aseptic Processing. The contracts were with APV Baker, Ltd, Crowley, United Kingdom for ohmic heating and the Twintherm Div. of Tetra-Laval, Lund, Sweden for split-phase aseptic processing.

We would like to thank Armand V. Cardello of the Consumer Research Branch, Behavioral Sciences Division, Science and Technology Directorate for conducting the sensory panel studies and Claire H. Lee of the Ration Development Branch, Ration Systems Division, Sustainability Directorate for performing the microbiological commercial sterility procedures on the products. They are all at the U.S. Army, Natick RD&E Center.

Citation of trade names in this paper does not constitute an official endorsement of the product.

FEASIBILITY OF APPLYING OHMIC HEATING AND SPLIT-PHASE ASEPTIC PROCESSING FOR RATION ENTREE PRESERVATION

1. INTRODUCTION

For many years the food industry has looked for processing systems capable of producing food products of excellent quality that are stable and safe under ambient distribution and storage conditions. There is also a need for a high-quality, low cost, and shelf-stable military ration that is acceptable to soldiers and can be packaged in many different kinds of containers, including biodegradable containers.

Thermal processing is often used for the preservation of military rations as well as commercial items. However, it may have deleterious effects on the sensory and nutritional properties of the preserved food. It would be desirable to have alternate methods of thermal sterilization that would produce fewer undesirable changes in the food.

Two novel methods that U.S. Army, Natick RD&E Center (Natick) has investigated are ohmic heating and split-phase aseptic processing. Both processes were developed in Europe.

Ohmic Heating (OH) works by electrical resistive heating and has the unique advantage of very quick and uniform heating of liquids and solids simultaneously, even of large particles, up to sterilization temperatures. Uniform heating means shorter process times and fresher-tasting, more nutritious foods. The system has a number of advantageous characteristics in that it:

1. Processes high solids foods: The even heating of solids and liquids means that products with up to 80% particulates can be processed without overcooking;

2. Assures particle integrity: very few moving parts together with careful plant design result in excellent retention of particle integrity up to a nominal 25 mm maximum cube size; diced vegetables remain firm and have sharply defined edges;

3. Enables rapid continuous processing: ohmic heating raises the temperature of most suspensions of solids to process temperatures of 265 ^{o}F (129 ^{o}C) or more in under 90 seconds, then cooling to 65 ^{o}F (18 ^{o}C) occurs in the flowing system within 20 minutes;

4. Ensures consistent quality: there are no hot surfaces and thus no burning or fouling;

5. Offers potential cost reduction by substitution of continuous processing of a high-temperature/short-time (HTST) nature for traditional batch retort operation at 255 ^{o}F (124 ^{o}C). There are also potential cost savings by the reduction of packaging material.

Split-Phase Aseptic Processing (SP) is designed to overcome not only the problem of conventional thermal processing, but also the limitations of conventional aseptic processing, which can only be applied to fluid or puree products. The system works by separately sterilizing the solid and liquid portions of the foods and aseptically packaging them together. Both solid and liquid portions receive an adequate amount of thermal effect, thus preventing overprocessing.

A number of recent articles have reported on these processes: Parrott, 1991; Swientek, 1991; Sastry and Palaniappan, 1992; Mans and Swientek, 1993. Consequently, a series of initial contracts was awarded to evaluate the technologies and to process a variety of foods that could then be compared to thermally processed military rations.

Preliminary processing was done in 1992 to demonstrate the feasibility of the two processes and to evaluate the representative products produced. When the preliminary studies were successful, subsequent contracts were awarded in 1993 so that a wide variety of foods, formulated according to military tray pack specifications, could be processed in sufficient quantities for sensory testing and possible long term storage testing.

2. EXPERIMENTAL

Ohmic Heating (OH)

Phase 1: Processing

The six products tested were: Carbonarra Sauce; Winter Soup; Mushrooms in Tomato Sauce; California Beijing Beef; Cappelletti; and Ratatouille.

The processing conditions are listed in Table 1. A description of the process is given in Appendix A.

Among the six products, all but Ratatouille (mixed vegetables) are low-acid foods ($pH \geq 4.5$) and therefore required sterilization. Mixed vegetables are high-acid foods because of the tomato sauce and therefore needed only pasteurization at

194 °F (90 °C) to render the ratatouille shelf stable.

A commercial sterility test was done by the contractor. All the samples passed. Appendix B is a description of the sterility test.

Table 1 - Processing Conditions for OH Products (Phase 1)

Product*	pH	Holding Time seconds	Temp.** °F (°C)	F_0 Value *** minutes
1. Carbonarra Sauce	5.8	70	270 (132)	14
2. Winter Soup (cream of vegetable)	5.4	70	271 (133)	18
3. Mushrooms in Tomato Sauce (a la Greque)	4.7	34	278 (137)	22
4. California Beijing Beef	5.4	109	266 (130)	14
5. Cappelletti	4.6	30	271 (133)	15
6. Ratatouille (mixed vegetables)	4.2	45	194 (90)	pasteur-ized

* ingredients are listed in Appendix C

** measured at end of holding tube

*** calculations based on Z value of 18

Phase 1: Sensory Testing

Procedures The six food products were initially examined by two food technologists and two sensory scientists. To characterize each product, sets of sensory attributes were developed. Nine-point scales, anchored on the ends by opposite descriptive terms were used to measure each attribute. Attributes and descriptors common to all six products were: color (light = 1 vs. dark = 9); appearance (a measure of visual consistency, 1 = very thin vs. 9 = very thick); and overall flavor intensity (weak = 1 vs. strong = 9). Because texture preservation of food particles was considered an important benefit of the OH process, a 9-point sensory texture scale and an integrity of pieces scale were developed to assess the major particulate ingredients on each product. For vegetable and pasta ingredients, texture scales were anchored very soft = 1 vs. very firm = 9. For meat (beef or smoked ham) ingredients, anchors were soft = 1 vs. tough = 9. In addition to the attribute scales, two other scales were used: a 9-point overall quality scale, where each point was anchored with descriptors, 1 = extremely poor to 5 = borderline/fair to 9 = excellent; a similarity scale (1 = not at all similar to 9 = extremely similar), in response to the question "All things considered, how similar is this product to one prepared in a restaurant?" From 19 to 22 food technologists, with experience in describing/judging quality of military rations, served as panelists. Two products were evaluated in each of three test sessions. Products were reheated in boiling water in their original plastic tubs and served warm, approximately 65 ^{o}C (150 ^{o}F). Samples were served one at a time in balanced order. Panelists were advised in writing that the recipes and flavor are typically British and that the purpose of the panel was to determine how effectively the process preserves the color, appearance, flavor and texture of the individual ingredients. Product names and ingredients lists were also provided.

Two products were tested each day. The means and standard deviations of the data were computed.

Results The rating means and standard deviations are presented in Table 2. The main observations, by attribute, are as follows:

Color - Of the group, Carbonarra sauce was perceived to be the lightest of the group and Beijing Beef the darkest. Each product, of course, had its own characteristic color, modified to various degrees by the particulate ingredients present.

Appearance - Ratatouille and Beijing Beef were perceived at approximately the midpoint of the Thin/Thick scale. The other products were rated thicker to varying degrees.

Flavor Intensity - All products were preceived to be moderately high in flavor intensity. Since an array of unique flavor types was represented by each one, this can be interpreted to indicate that the OH process was effective in preserving flavor integrity.

Texture - (First scale - vegetable or pasta ingredients, as indicated in Table 2) Vegetable ingredients in the Beijing Beef and the pasta in the Cappelletti item rated approximately midway between very soft and very firm. The corn in the Carbonarra and the vegetable ingredients in the Winter Soup item were rated firmer. Rated firmest in the product group were the mushrooms in the Mushrooms/Tomato Sauce product. On the "Integrity" scales, the same ingredient items were rated very high (whole/unbroken). The lowest rating was for vegetables in Beijing Beef wherein the attribute may have been more difficult to judge because of the dark brown gravy.

Table 2 - Sensory Analysis of OH Products

Attribute **	1* $\bar{X}$ σ (sauce)	2* $\bar{X}$ σ (soup base)	3* $\bar{X}$ σ (sauce)	4* $\bar{X}$ σ (sauce)	5* $\bar{X}$ σ (sauce)	6* $\bar{X}$ σ (sauce)
Color	3.2±1.0	4.9±0.9	6.2±1.1	7.1±1.2	6.3±1.0	6.1±0.9
Appearance	6.9±0.9	6.3±0.9	6.7±1.0	5.5±1.3	7.0±0.7	4.6±1.3
Overall Flavor Intensity	6.9±1.1	6.6±1.2	6.5±1.4	7.0±1.2	6.4±1.5	6.4±1.2
	(corn)	(veget-able)	(mush-room)	(veget-able)	(cappel-letti)	(zucch-ini)
Texture	6.2±1.4	6.3±0.8	7.5±1.0	4.8±1.5	4.6±1.2	6.6±1.3
Integrity of Pieces	8.4±0.7	8.4±0.7	8.7±0.6	6.6±1.4	7.7±1.5	7.7±1.4
	(ham)	(ham)		(beef)	(zucch-ini)	(pepper)
Texture	5.8±1.4	6.3±1.2		4.7±1.5	4.2±1.5	6.8±1.2
Integrity of Pieces	8.3±0.7	8.4±0.6		7.7±1.2	5.6±1.8	8.0±1.1
Overall Quality	7.3±1.1	7.5±1.0	7.5±0.7	6.7±1.2	7.3±1.1	7.6±0.8
Similar to Restaurant	6.4±1.9	6.7±2.2	6.6±2.1	5.7±2.2	7.1±1.5	7.3±1.66

* Refers to products listed in Table 1

** Attributes are listed in the order rated.

Texture - (Second scale - meat or other vegetable ingredients, as indicated in Table 2) The sliced zucchini in the Cappelletti item and the beef ingredient in the Beijing Beef item rated near the midpoint ot the soft firm/tough scale and the vegetable or ham ingredients in the other products were rated tougher/firmer.

Overall Quality - Ratings for all products, except the Beijing Beef, ranged between good and very good on the quality scale. Although no other heat processed products of the same kind were available for comparison, the sensory results of this first effort were impressive.

Similarity of products to those prepared in a restaurant - Products the panel considered most similar were the Cappelletti and Ratatouille items. The Beijing Beef was considered least similar.

Conclusions

The sensory evidence suggested that OH is a promising techcnology for producing high quality shelf stable military rations. Its adoption may make possible both individual and bulk packed field rations approaching A-ration quality. The most notable quality benefits appear to be retention of sensory texture and physical integrity of food pieces.

It is expected that ohmic processing technology will be adaptable to nutrient retention, particularly of heat labile vitamins. This may also be a benefit since vitamin retention in heat processed foods generally depends more on processing time than the temperature used. The high temperature/short time OH should maximize their retention.

If adopted, OH can be used with field ration packaging systems envisioned for the future such as polymeric or biodegradable containers.

Phase 2: Processing

Phase 1 demonstrated that ohmic heating can be applied to the production of shelf-stable entrees that use specially designed formulations. For Phase 2 a contract was awarded to prepare products that were selected from a list of MRE entrees and tray pack rations, especially those that are highly desired by the soldiers but currently fail in quality due to excessive thermal processing. The items for processing were selected after a discussion with the Natick food technologists who develop new rations and improve the quality of current MREs and tray pack items. The formulations are listed in Appendix C. Table 3 lists the processing conditions.

After processing, sterility testing was done and the products were shown to be completely sterile.

A Sensory evaluation was conducted with similar items prepared with split-phase aseptic processing (SP) and conventional thermal retort processing (TP). This will be discussed later.

Split-Phase Aseptic Processing (SP)

Phase 1: Processing

Four products were processed in this phase. They were chosen as representative products after discussions with Natick food technologists. The items are listed in Table 3.

Table 3 - Processing Conditions for OH Products (Phase 2)

Product	pH	Holding Time seconds	Temperature* °F	°C	F_o Value minutes
1. Corned Beef Hash	5.7	81	271	133	20
2. Chicken Chow Mein	6.0	128	267	131	20
3. Pork in BBQ Sauce	5.2	104	271	133	25
4. Macaroni Twists in Butter Sauce	6.8	40	275	135	15
5. Potatoes in Butter Sauce	5.8	68	272	133	15
6. Beef Chunks in Gravy	5.7	104	271	133	15
7. Strawberries in Syrup	3.0	42	203	95	18

* Measured at end of holding tubes

Table 4 presents the processing times and the corresponding F_o values. A description of the process is given in Appendix D.

Table 4 - Processing Conditions SP Products (Phase 1)*

Product	Process Time minutes	F_o Value Range ** minutes
1. Mixed Vegetables	20	8.5 to 22.7
2. Macaroni and Cheese	13	5.5 to 17.8
3. Pork BBQ	12	8.0 to 15.3
4. Beef Stew	15 - 17	6.5 to 24.4

* Data reported here are for particulates in the particle tank. All the sauce portions were processed at the same conditions as described in Appendix D.

** F_o values calculations were based on the temperature taken by a naked thermocouple at the cold spot and simultaneously translated into F_o values.

In general the processing went well despite a lack of prior experience of the contractor in formulating the military specified ingredients. When sterility tests were done, all plate counts were negative. This demonstrated that the Twintherm process can provide sterile products with significantly reduced processing times when compared to a conventional retort process.

However, some lessons were learned:

1. "military beef" pieces were too large, approximately 1. 5 to 2 inches (3.8 to 5.0 cm) to pass through the feeding tube of the packaging machine which had an inner diameter of 0.75 inches (1.9 cm). Customized beef should have been ordered

2. It would have been much more efficient and risk-free if the contractor were to provide all the ingredients. The quality of the raw ingredients would have been better and the processing plant delivery schedule easier to control;

3. The dry macaroni should have been precooked so that it gained water to 2.5 to 3.0 times its original mass, instead of the 2.0 times as specified in the retort process. The retort process, due to its long-time low-temperature nature, allows macaroni to continue absorbing moisture from the sauce during processing. On the other hand, the Twintherm method was a short-time, high-temperature process. Thus there is insufficient time during the solids processing to further rehydrate the macaroni. Also, there was not enough time to absorb moisture from the sauce after mixing. There was a visible unrehydrated ring in the center of the macaroni that impaired the final sensory scores.

Phase 2: Processing

The products that were processed in this phase and the processing conditions are listed in Table 5. All the runs were done with the stirring/steam injecting bar set at a 45 ^{o} angle and a speed of 23 rpm.

Table 5 - Processing Conditions for SP Products (Phase 2)

Product	Heating Time minutes	Cooling Time minutes	F_o Value Range minutes
1. Potatoes in Butter Sauce	11.17	12.00	5.8 - 47.9
2. Pork in BBQ Sauce	7.50	6.50	7.6 - 25.3
3. Chicken Chow Mein	7.33	8.00	7.9 - 23.0
4. Chili with Macaroni	8.25	8.00	6.3 - 38.6
5. Beef Chunks with Gravy	4.67	4.82	8.8 - 16.6
6. Mixed Vegetables`	8.50	25.00	8.5 - 18.4
7. Spaghetti with Meat Sauce	11.33	7.00	6.4 - 34.3
8. Beef with Mushrooms	5.67	7.00	9.9 - 28.6
9. Macaroni and Cheese	5.50	10.00	8.2 - 25.8
10. Strawberries in Syrup	6.33	13.00	Pasteurized

Phase 2: Sensory Testing

The seven OH products (Table 5) and the 10 SP processed products (Table 6) were examined informally by a group of food technologists and sensory scientists. After individual assessment of flavor and texture, a group discussion was held to note product charcteristics and to select representative items for subsequent consumer sensory panel testing. Three items were selected that (1) had been processed both by OH and SP; (2) were made using current military specifications (minor changes for OH and SP processes); and (3) had the existing equivalent tray pack or Meal Ready to Eat (MRE) item. Products selected were Potatoes in Butter Sauce, Pork in Barbecue Sauce, Chicken Chow Mein and Chili with Macaroni.

Procedure Products were evaluated in four separate consumer-type panel sessions using randomly selected Natick employee volunteers. All products were reheated in boiling water in their original containers. The serving temperature was approximately 65 ^{o}C (150 ^{o}F). The samples were presented monadically to panelists in counterbalanced order. Since texture of particulate ingredients was of particular interest, the panel was asked to rate the level of chewiness of the meat ingredient and, in the case of the potato item, firmness; a 9-point intensity scale was used, where 1 = the lowest level of the attribute and 9 = the highest level. Acceptability was rated using the 9-point hedonic scale. Additional comments were solicited.

Because informal examinations indicated differences in spicing between the SP and MRE Chili with Macaroni products, consumer panelists were also asked to assess Quality of Spice on the quality scale described previously and Mouth Heat on a 9-point, none to extreme, intensity scale. An analysis of variance was computed separately for attribute and acceptability ratings to determine if differences among processes were significant. When *F* ratios were significant at $P \leq 0.05$, a post hoc Newman-Keuls test was used to determine significance of differences among means.

<u>Results</u> Significant differences occurred among each of the four product sets in texture (Table 6). The differences, however, were discounted due to observations/knowledge that the key ingredients were from different sources, were different in dimension and pretreated differently. Of particular concern was the poor visual and physical condition of the potato dices in the tray pack Potato/Butter Sauce product.

Table 6 - Sensory Results for OH, SP and TP Products (Phase 2)

A - Products tested against Tray Pack - 37 panelists

Attribute	OH $\bar{X}$ σ	SP $\bar{X}$ σ	Tray Pack (TP) $\bar{X}$ σ
1. Potatoes in Butter Sauce			
Texture	4.71±1.43	3.82±1.52	4.82±1.71
Overall Acceptability	4.76±1.99[a]	5.03±2.03[a]	4.58±2.15[a]
2. BBQ Pork			
Texture	4.32±2.01	5.92±2.27	6.34±2.11
Overall Acceptability	5.39±1.87[a]	5.61±1.52[a]	5.97±1.55[a]
3. Chicken Chow Mein			
Texture	5.70±1.85	6.54±2.18	4.51±1.68
Overall Acceptability	6.11±1.74[a]	5.16±2.41[b]	5.49±2.08[ab]

B - Product tested against Meal Ready to Eat (MRE) - 38 panelists

	SP	MRE
Attribute	$\bar{X}$ σ	$\bar{X}$ σ
4. Chili with Macaroni		
Quality of Spice	5.61 ± 1.87^{b}	6.00 ± 1.6[illegible]
Mouth Heat	6.37 ± 1.15^{a}	4.00 ± 1.92[illegible]
Chewiness	6.50 ± 1.41^{a}	4.92 ± 1.24^{b}
Overall Acceptability	6.24 ± 1.48^{a}	6.26 ± 1.35^{a}

Acceptability results indicated:

(1) A potential acceptance problem with the Potatoes with Butter Sauce product, regardless of process. Panelists were, on average, neutral toward all three products, suggesting that the problem may be the item itself, not the processing method.

(2) TP Pork with Barbecue Sauce was rated somewhat higher in acceptabiity than products from the other processes, but differences were not significant. Variations in the barbecue flavor were noted among products;

(3) The OH Chicken Chow Mein rated significantly higher than the SP product. The TP item was not significantly different from the other two processes.

(4) For the Chili with Macaroni product, MRE Spice Quality was considered significantly better than SP, Mouth Heat and Chewiness of the meat ingredient was significantly higher in the SP product but acceptability ratings were identical.

Sensory acceptability results suggested that, at the present state of product development, the OH and SP processed items are equivalent to their counterpart TP and MRE items now in the military ration system. Further optimization of formulas for OH or SP appears feasible because of the evidence presented in Phase 1 using the contractor's formulations.

3. DISCUSSION OF RESULTS

OH technology is attracting more and more interest from both industry and academia because of its ability to retain physical, chemical and sensory qualities -- a unique advantage that few thermal technologies can match. In order to secure

FDA/USDA approval for this process, Natick has the unique ability to apply an intrinsic chemical marker approach to validate the sterility of the OH products -- one of the most stringent requirements to receive approval of new processing methods.

SP, on the other hand, has gradually emerged in the European market but at a much slower pace. It is a sound and practical technology. Few machinery modifications are needed to further reduce the physical damage to the particulates and the range of the F_0 distribution within the vessel. A continuous, scale-up unit will certainly improve the quality of food, as well as reduce the processing cost.

Both OH and SP are designed to overcome the product quality loss caused by conventional retort processing. Their technologies demonstrate advantages when the formulation is adequately tailored and premium ingredients are used. Fresh vegetables should be used whenever possible. Both processes have merit as a technology insertion for the future Family of Operational Rations (FOR).

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APPENDIX A - DESCRIPTION OF OHMIC HEATING

Basic Principle

Ohmic heating occurs when an electric current passes through a food that has an electrical resistance. Energy is generated by equation 1:

$$E = I^2R \tag{1}$$

Where: E = voltage energy

I = current

R = electrical resistance

Sastry and Palaniappan (1991) have written:

'The basic relationship for the energy-generation rate of a food under ohmic heating is that shown in equation 2."

$$\mu = [\Delta V]^2 \sigma \tag{2}$$

Where: μ = energy-generation rate per unit volume

ΔV = voltage gradient

σ = electrical conductivity

The critical property affecting energy generation is μ. For most solid materials undergoing conventional heating, μ increases sharply with temperature around $60^{\circ}C$ as as result of breakdown of cell wall materials. If ohmic heating is used the relationship between μ and temperature T becomes linear as the electric field strength E is increased, possibly as a result of electro-osmotic effects, which could increase the effective conductivity at low temperatures (Palaniappan and Sastry 1991).

Process

A schematic diagram of the equipment used is shown in Figure 1. Ingredients are pumped to an ohmic heating column where the electrical current is controlled so that the desired processing temperatures occur. The food is processed within the column. After processing the food is sent to a holding tube and then to a cooler. After cooling, the sterilized product is sent to an aseptic filler where it is packaged.

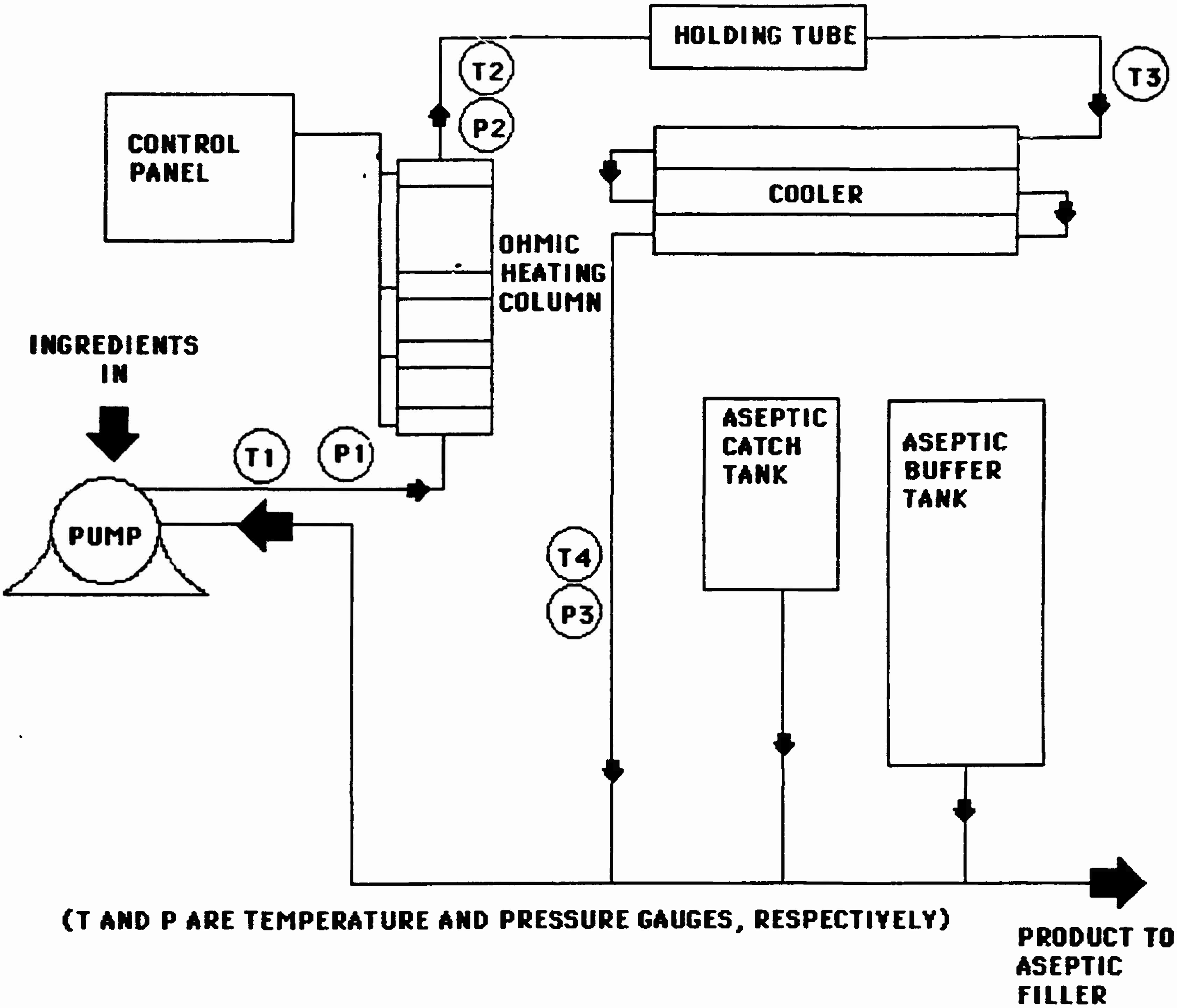

FIGURE 1 - SCHEMATIC DIAGRAM OF OHMIC HEATING

APPENDIX B - COMMERCIAL STERILITY TESTING PROCEDURE

1. Commercial Procedure

A total of 40 samples were randomly selected during aseptic filling and subjected to a routine sterility check.

Preincubation

The samples were divided among preincubation temperatures of 30, 37 and 55 ^{o}C for 14 days prior to examination. During this period the external pack condition was monitored.

Examination

All samples were examined as per the laboratory standard method for aseptically filled low-acid foodstuffs. Aliquots of product were aseptically removed from each pack and inoculated into the following recovery media:

A. Preincubate at 37 and 55 ^{o}C: Two tubes each of TDB broth (aerobic cultures) and PPYS agar media (aerobes) at each temperature.

B. Preincubate at 30 ^{o}C: Two tubes of PPYS agar media (anaerobes) and a single 9 mm streak plate of Oxoid Nutrient agar media (aerobes).

C. Incubate all cultures for 7 days.

D. The samples were examined by direct microscopy and the pH measured.

2. Natick Procedure

Incubate the packages at 30 to 35 ^{o}C for 10 days and observe daily for swelling.

Preparation of packages before opening

A. Wash in lukewarm detergent-water solution and rinse thoroughly with cold water.

B. Wipe dry with disposable paper towels.

C. Submerge one end of package in 80% ethyl alcohol for 5 to 10 minutes. Remove package from alcohol and place in a sanitized or sterile beaker with the end that has been sanitized in an upward position and place in a laminar flow hood that has been sanitized by disinfectant.

D. Cut the end of the package that had been sanitized with sterile scissors.

Microbiological Analysis

A. Aseptically transfer 10 g of product with a sterile spoon into a stomacher bag and dilute with Butterfield's phosphate buffer, pH 7.2, to make a 10^{-1} dilution, then stomach for 2 minutes.

B. Document the appearance and odor of the product.

C. Aseptically transfer the remainder of the original product into a sterile Wirlpak™ bag for storage at 0 to 4 °C.

D. Prepare a slide for direct microscopic examination of the stomached sample.

E. Aseptically transfer 1 mL of the stomached sample for aerobic plate count (APC; Standard Plate Agar) and yeast and mold count (Potato Dextrose Agar). A pour plate technique is used. Incubate the plates at 30 °C (48 hours for APC's and 5 days for yeast and mold counts).

F. Obtain the pH by immersing an electrode directly into the product.

References

American Public Health Assoc., 1992; Compendium of Methods for Microbiological Examination of Foods, 3rd Ed., M.L. Speck.

Assoc. of Official Analytical Chemists, 1990; Official Methods of Analysis, 15th Ed. Vol. I and II.

Food and Drug Administration; 1992 Bacteriological Analytical Manual, 7th Ed.

APPENDIX C - PRODUCTS AND INGREDIENTS

Product and Ingredients		% in OH	%in SP	% in TP
Beef Chunks with Gravy (50% beef/50% gravy)				
Water		27.55	identical	34.50
Starch		3.50	to TP	2.63
Salt		(in beef mix)		0.63
Sugar		0.20		0.25
Emulsifier (Lecithin)		0.05		0.13
Ground celery seed		0.02		0.025
Onion powder		1.00		1.25
Tomato paste		1.50		2.00
Garlic powder		0.01		0.015
Ground allspice		0.01		0.01
Frozen mushrooms		3.40		4.25
Groundnut (peanut) oil		2.00		2.50
Beef flavor		0.70		1.75
Black pepper, ground		0.05		0.06
Bay leaves, ground		0.01		0.01
Nutmeg, ground		0.004		0.05
Beef mix		60.00		50.00
Diced beef	50.00			
PP590 Isolated soy Protein	2.00			
Salt	0.51			
Naturoma™ Roast Beef 1150	0.20			
Water	8.229			
Beef with Mushrooms (43% beef/10% mushrooms/47% sauce)				
Beef		--	identical	43.00
Mushrooms		--	to TP	10.00
Water		--		37.25
Dry Cream		--		4.01
Onion, chopped, dehydrated		--		2.73
Starch		--		1.36
Salt		--		0.72
Braised beef Ffavor		--		0.15
Mustard flour		--		0.46
Lecithin		--		0.23
Black pepper, ground		--		0.04
Allspice, ground		--		0.03
Garlic powder		--		0.03

Product and Ingredients	% in OH	% in SP	% in TP
Beef Stew			
Beef, diced, cooked	--	identical	40.75
Water	--	to TP	27.00
Potatoes, diced	--		15.00
Carrots, diced	--		7.50
Peas	--		2.95
Starch	--		2.00
Tomato paste, 30% solids	--		2.00
Margarine	--		1.50
Salt	--		0.50
Sugar	--		0.32
Onion powder	--		0.17
Hydrolyzed vegetable protein	--		0.11
Black pepper, ground	--		0.08
Celery, soluble	--		0.06
Garlic powder	--		0.01
Caramel color	--		0.06
California Beijing Beef			
Beef	25.00	--	--
Water	32.08	--	--
Carrots	6.00	--	--
Green beans	2.00	--	--
Onion, chopped	5.00	--	--
Peas	5.00	--	--
Red pepper	5.00	--	--
Green pepper	5.00	--	--
Baby corn	2.00	--	--
Dark soy sauce	4.87	--	--
Dry sherry	2.93	--	--
Starch	2.90	--	--
Sugar	1.95	--	--
5 Spice emulsion	0.13	--	--
Ginger spice emulsion	0.013	--	--
Orange oil, sweet	0.0022	--	--
Chili spice emulsion	0.0016	--	--
Star anise, ground	0.02	--	--
Salt	0.10	--	--

Product and Ingredients	% in OH	% in SP	% in TP
Cappelletti in Tomato Sauce			
Cappelletti	10.00	--	--
Onion, chopped	10 .00	--	--
Courgettes, sliced	66.33	--	--
Sugar	1.00	--	--
Starch	1.00	--	--
Salt	0.70	--	--
Basil, frozen	0.90	--	--
Black pepper, ground	0.07	--	--
Carbonarra Sauce			
Milk, whole	44.43	--	--
Gammon, diced, smoked	25.00	--	--
Sweet corn, canned	15.00	--	--
Double cream	9. 00	--	--
Starch	3.10	--	--
Lemon juice	1.00	--	--
White wine, dry	1.00	--	--
Olive oil	0.70	--	--
Garlic puree	0.35	--	--
Salt	0.21	--	--
Frimulsion SH™	0.14	--	--
White pepper, ground	0.07	--	--
Chicken Chow Mein			
Water	24.71	identical	30.86
Chicken, cooked, diced*	35.00	to TP	28.00
Celery, fresh, blanched or dehydrated	14.13		14.13
Been sprouts, drained	6.00		7.00
Mushrooms, drained	6.00		6.00
Water chestnuts, drained	7.00		6.00
Chicken fat	2.40		2.40
Starch, food, modified, high opacity	2.25		2.25
Soy sauce	1.50		1.50
Salt	(in chicken)		C.85
Onion, dehydrated, chopped	0.50		0.50
Sugar, white, granulated	0.44		0.44
Pepper, white, ground	0.07		0.07
* Chicken (% weight of chicken)			
Water	12.38		3.00
Soy isolate	2.00		--
Salt	0.86		1.00
Chicken flavor	1.43		--
Sodium tripolyphosphate	--		0.25

Product and Ingredients	% in OH	% in SP	% in TP
Chili with Macaroni			
Beef	--	identical	40.69
Macaroni	--	to TP	15.00
Water	--		27.58
Tomatoes, crushed	--		6.38
Tomato paste, 26% solids	--		4.68
Chili powder	--		1.87
Starch	--		1.28
Onions, dehydrated, chopped	--		0.85
Salt	--		0.81
Sugar, light brown	--		0.64
Lecithin	--		0.21
Black pepper, ground	--		0.03
Corned Beef Hash			
Beef, cured, blanched*	43.65	--	43.50
Potato, fresh	45.00	--	45.00
Water	7.36	--	6.87
Potato, crushed, dehydrated	1.65	--	1.65
Salt	0.75	--	1.24
Onion, dehydrated, chopped	0.72	--	0.72
Sugar, white, granulated	0.60	--	0.60
Garlic powder	0.17	--	0.17
Pepper, green, sweet, dehydrated	0.15	--	0.15
Pepper, black, ground	0.07	--	0.07
Bay leaves, ground	0.025	--	0.025
Clove, ground	0.008	--	0.008
* Cured beef (% weight of beef)			
Water	14.88		2.50
Sodium erythorbate	0.047		0.05
Sodium nitrite	0.015		0.015
Soy isolate	1.89		--
Salt	0.80		--
Beef flavor	0.55		--

Product and Ingredients	% in OH	% in SP	% in TP
Macaroni in Butter Sauce			
Macaroni twists	10.00	--	31.13
Water	80.49	--	41.47
Margarine	4.90	--	4.13
Starch	0.50	--	1.03
Salt	0.50	--	1.03
Garlic powder	0.20	--	0.21
Lecithin	0.15	--	0.17
Butter flavor	0.18	--	0.08
Pepper, white	0.08	--	0.07
Annatto, dry	0.01	--	0.007
Olive oil	0.005	--	--
Macaroni and Cheese			
Macaroni	--	identical	57.00 to 75.00
Water	--	to TP	34.36 to 19.98
Cheese, cheddar, dehydrated	--		4.30 to 2.50
Margarine	--		1.98 to 1.15
Starch	--		1.08 to 0.63
Cheddar cheese, flavoring	--		0.65 to 0.38
Salt	--		0.43 to 0.25
Lecithin	--		0.11 to 0.06
Mustard flour	--		0.065 to 0.038
Pepper, white	--		0.034 to 0.020
Annatto, dry	--		0.003 to 0.002
Mixed Vegetables (65% vegetables/35% brine)			
Green beans	--	identical	16.34
Carrots, diced	--	to TP	16.34
Corn, sweet	--		16.34
Green peas	--		8.50
Green lima beans	--		7.84
Mushrooms in Tomato Sauce (a la Greque)			
Mushrooms, fresh	40.00	--	--
Tomato, chopped, canned	34.85	--	--
Onion, chopped	16.55	--	--
Tomato puree	4 .00	--	--
Starch	2.00	--	--
Salt	1.00	--	--
Olive oil	0.50	--	--
Thyme	0.33	--	--
Oregano	0.33	--	--
Garlic puree	0.34	--	--
Black pepper, ground	0.10	--	--

Product and Ingredients	% in OH	% in SP	% in TP
Pork with BBQ Sauce			
Pork*	60.00	48.34	40.00
Tomato paste, 24% solids	22.50	14.24	24.40
Water	13.82	13.96	14.08
Sugar, brown, light	4.40	4.35	4.40
Vinegar, cider	3.32	3.28	3.32
Starch, waxy maize, modified	2.00	1.20	1.20
Salt	0.08	0.60	0.60
Worcestershire sauce	0.60	0.60	0.60
Onion, dehydrated, chopped	0.38	0.38	0.38
Pork flavoring	(in pork)	0.20	0.20
Smoke flavoring	(in pork)	0.20	0.20
Mustard flour	0.20	0.20	0.20
Garlic powder	0.20	0.20	0.20
Lecithin	--	0.08	0.12
Red pepper, ground	0.04	0.04	0.04
Clove, ground	0.04	0.04	0.04
Allspice, ground	0.012	0.012	0.012
Cinnamon, ground	0.01	0.008	0.01
* Pork (% weight of pork)			
Water	13.48		
Soy isolate	2.00		
Salt	0.84		
Smoked pork flavoring	0.33		
Potatoes with Butter Sauce (65% potatoes/35% sauce)			
Potatoes	50.00	identical	65.00
Water	40.19	to TP	26.27
Margarine	5.50		5.25
Olive oil	0.50		0.50
Starch	2.00		1.75
Sugar	0.60		0.53
Salt	0.75		0.85
Emulsifier	0.15		0.09
Calcium chloride	0.08		0.07
Calcium disodium EDTA	0.013		0.006
Ground white pepper	0.06		0.05
Ground celery seed	0.012		0.011
Butter flavor 57.t.616	0.15		0.11

Product and Ingredients	% in OH	% in SP	% in TP
Ratatouille			
Tomato, chopped, canned	47.94	--	--
Courgettes, sliced	15.00	--	--
Onion, chopped	12.50	--	--
Red pepper, diced	10.00	--	--
Green pepper, diced	5.00	--	--
Sugar	2.59	--	--
Olive oil	2.43	--	--
Salt	1.00	--	--
Basil	1.00	--	--
Starch	0.77	--	--
Oregano	0.50	--	--
Garlic puree	0.47	--	--
Lemon juice	0.41	--	--
Tomato booster	0.30	--	--
Black pepper, ground	0.09	--	--
Spaghetti with Meat Sauce			
Spaghetti	--	identical	17.00
Ground beef	--	to TP	27.00
Water	--		25.40
Tomatoes, crushed or diced	--		14.30
Tomato paste, 26% solids	--		10.54
Parmesan cheese	--		1.70
Salt	--		1.04
Starch	--		1.04
Onions, chopped, dehydrated	--		1.00
Sugar	--		0.62
Garlic powder	--		0.14
Onion powder	--		0.083
Oregano, ground	--		0.066
Basil, ground	--		0.033
Red pepper, ground	--		0.025
Thyme, ground	--		0.008
Bay leaves, ground	--		0.008
Strawberries with Syrup			**(cherries)**
Water	14.00		13.30
Sugar	10.00		17.60
Lemon juice vs. salt	4.00		0.10
Starch	2.00		3.00
Strawberries or cherries	70.00		66.00
Color, Red No. 40. FD&C	--		0.001

Product and Ingredients	% in OH	% in SP	% in TP
Winter Soup			
Potato 1	10.44	--	--
Potato 2	7.46	--	--
Leek	11.94	--	--
Peas	7.46	--	--
Green beans	7.46	--	--
Carrots	7.46	--	--
Gammon, smoked	8.36	--	--
Onion	4.18	--	--
Butter	5.67	--	--
Single cream	2.69	--	--
Chicken stock powder	1.05	--	--
Water	23.90	--	--
Vegetable oil	0.90	--	--
Starch	0.45	--	--
Frimulsion™	0.19	--	--
Salt	0.30	--	--
White pepper	0.09	--	--

APPENDIX D - DESCRIPTION OF SPLIT-PHASE ASEPTIC PROCESSING

Basic Principle

Aseptic processing is the general application of high-temperature short-time conditions to the product followed by aseptic packaging. It has generally been limited to liquids or at the most, liquids that contain particles of minute size. The Twintherm™ system overcomes this limitation by sterilizing the solids and the liquid separately.

Process

A schematic diagram of the process is shown in Figure 2. The process consists of the following steps.

Sauce Phase

The sauce phase was mixed in a 500 L (132 gal) horizontal tank and heated to about 75 ^{o}C (137 ^{o}F) by the steam jacket on the tank. All the sauces were processed in the same way, i.e. 130 ^{o}C (214 ^{o}F) for 1.1 minutes [2 Contherm™ heaters, 4.5 inch (10.2 cm)] and cooled down to about 40 ^{o}C (88 ^{o}F) (3 coolers, 4.5 inch rotor, staggered) at a capacity of 220 kg (484 lb) per hour. The sauce was collected in a mobile aseptic tank and then transferred and docked to the particle tank. The sauce phase received an F_o value of about 4 to 5 in the fastest moving segment (laminar flow V_{max} = 2 x V_{ave}).

Particle Phase

The particles were sterilized in 100 kg (220 lb) batches by injection of steam. This means that there will be about 25% condensate added to the particles, which must be considered when calculating the sauce recipé. The temperature in the tank was measured with a number of thermocouples at different places. The temperatures were recorded in a data logger where F_o values were also calculated concurrently. The different particle batches were processed to an F_o value of about 7 (naked thermocoupl\es) which means that an F_o value of about 4 to 5 was obtained in the

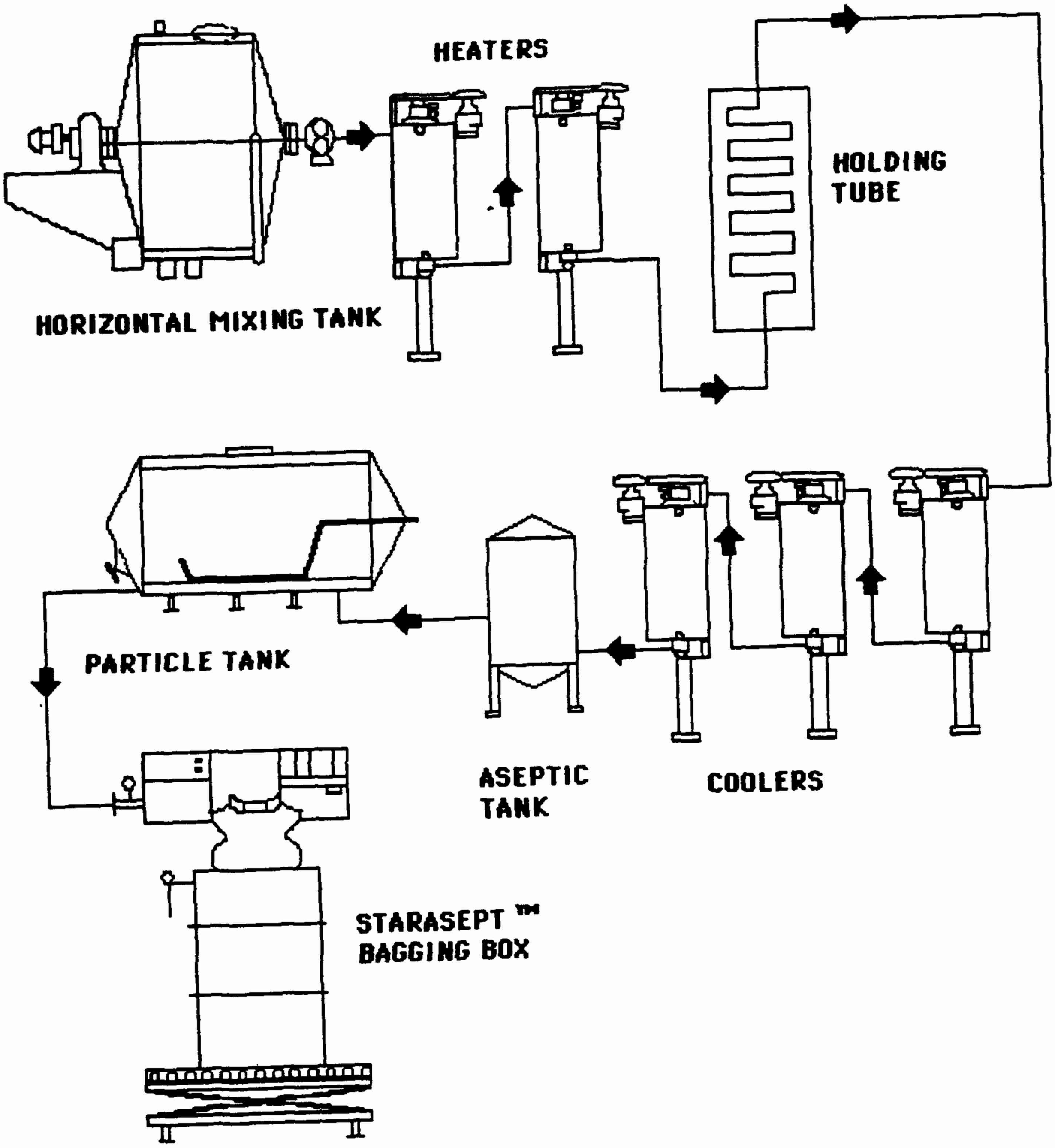

FIGURE 2 - SCHEMATIC DIAGRAM OF SPLIT PHASE ASEPTIC PROCESSING

center of a particle of the type that was used (maximum dimensions 10 m (0.4 in) on a side.

Packing

The sauce was processed with sterile air from the mobile Steritank™ to the particle tank, where it was mixed together in the final product. The product was then packaged in 5 L (1.32 gal) aseptic bags in the StarAsept™ filler. In a commercial plant there is a horizontal aseptic tank between the particle tank and the filling machine, where it has a good mixing effect. In the laboratory the mixing takes place in the particle tank, where the mixing is optional, resulting in a particle distribution that is not even. (There are more particles in relation to sauce in the beginning or in the end, depending on particle density. The bags were filled to about 3 to 4 kg (6.6 to 8.8 lb) and then incubated for about 10 days before packing in paper boxes.